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CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

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LINER EXPANDER

This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

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Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

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A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lover sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such 10 as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft 16.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein $\mathbf{P_c}$ is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A end B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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- 1 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said 2 3 shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member К from said shaft, and a constant force spring member positioned on said shaft 8 to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against 9 10 said liner by a substantially constant force.
 - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said cone member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
 1 5. The device of Claim 3 wherein said compression means comprises
- 5. The device of Claim 3 wherein said stop means comprises a sleeve-like element connected to said movable bearing plate member and slidably positioned on said shaft and a member connected to said shaft to limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
 - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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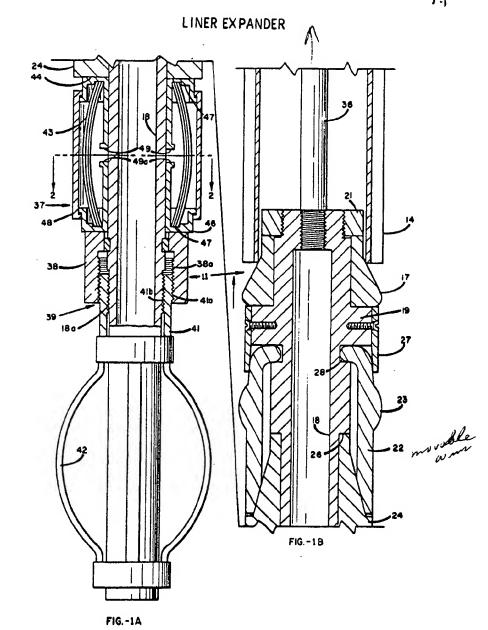
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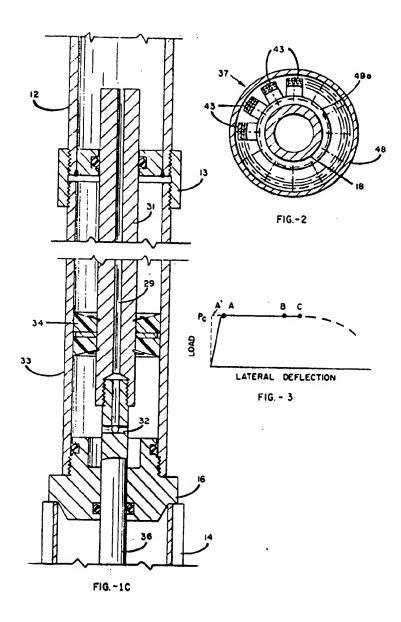
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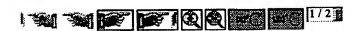
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1. A dorice for expending a schallin liner inside a candid which device comprises a short element, an expending the number obtained to said short closests, said die member comprising a movelle liner-forming member positioned on said short and being methally movelle in respect thereof to contact said liner, as expender member alidably positioned on said short between said shorts and scale die member to move said liner-forming member from said shorts, and a constant force spring member positioned on said shorts to contact said expenses springs and to extend a spring member against said liner-forming member, whereby said liner-forming member is unjed against said liner-forming member, whereby said liner-forming member is unjed against said liner by a substitutially constant force.

E. In a device for installing an expended mobilic liner in a combait wherein as expanding the is moved through a liner positional in said souther to expend said liners a cylindrical start almost, an expending sly massher withhold to said shart, said the wester comprising a plusality of arm members discress around said shart, and teing provibile extensity therefore to contact still liner, a cons member alidably positioned on said shaft between said shaft and said arm members to carp said arm answers consartly from said shaft, and a constant force opplies member positioned on said staffs to contact stid cone number and to maintain said cone member in contact with said are members, whereby said age numbers are urged outpartly by a substantially constant force,

3. Two device of Claim 2 shareds said someters force spring souber comprises a plumility of commun disposed around said shart, a first boaring plate sumber and a second bearing plate souber, each of said boaring plate members contacting opposite rods of said columns, at least one of said bearing plate members being sovebly positioned on said shaft and being in contact while said come number, stop means commerted to said staff to limit the axial traval of said moveble bearing plate number along said staft, and compression means for maintaining a lateral deflortion in said columns.

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- . A. The device of Claim 3 wherein said compression group comprises a differential survey equipmenting until againg number and said shaft.
- 5. The device of Chain 3 wherein sold shop means comprises a alasma-like elecant commented to said sowable bearing plate number and distably positioned on said shaft and a sunfer commuted to said shaft to limit the travel of said alasma.
- 6. The device of thate 3 whereis said columns have a mechangular aross-scotion, the width being greater than the thicknows, and having the pider face ground to the discretor of main shart.
- 7. A device for installing on expended soballic liner to a contact which comprises a sylindrical shaft classical on separating the sessor sounted on mid shall, said the senter scappining a plantity of tru someone disp cirmsfareshially around the outside of said shaft and being pleotable notmarkly therefrom to content the liner; a scalest anymhing genter slidebly positioned on said short between said shaft and said are members to says said store cetuardly from suid shaft; a plurality of alander columns, each beving a long reutingular cross-section and disposed sireuccharactally about suid chaft; an upper bearing plate member and a lower bearing plate scatter, and slikelily positioned on sale shaft and contenting opposite order of sale columns limiting alsows absorbed to sook of stds tearing plats numbers and alidably positioned an acid staft; a aboulder mader on said shaft; a fifth-manial server elements connecting with shoulder and said shorts to apply Ling look to said enimary unid shoulder being consequable with the ctof to entil lessor bearing plate mester, werety the arial travel of each bearing plate numbers is limited; said column vanders nessitting their buckling lood to eald now rembers to urgs said and spokers estaurally with a substantially constant force.

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LITER EXPANSES

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Beginning, a sathon and apparatus have been developed for installing on expanded setablic lines as on cal well or other opedall, Explosilly, a surroyated attack liner is immerted in a conduct which he has be hired, the greatest parighosal-disconton of the liner being slightly less Seeses at Lout patheograph, An expending tool is pessed through the liner placed in the conduit, and a first-stone expanding dia senses a gross plantic doformation of the liner, which is supersied outwardly the inside of the ecoluit. A season-stage file on the tool than provides an additional firms defendation of the limes to provide a smoother, con the constant and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die sugplies the expanding force for the second-stage die, which expanding force is a street function of the strength, or wall thickness, of the combuit is which the liner is being installed. For example, in himing oil well cusing, heavy application of the greet forces required may result in raphar of the casing reasing the impulling tool. In fasteness where the internal ndult is ecoupled less than their enticipated, the resultwhe tool to become similar to the calling or otherwise ever spring arrangement to employed in economican with the secondstage dis, various difficulties are encountered in obtaining a spring miss beving the desired strength is continution with the other spring. characteristics, and with the tool drauging against the incide well of the conducts after bring passed through the limer.

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fince tools of the type mentioned above of but are employed in welldeep in the ground, it is highly preferable that a tool be used which mader no circumstances will become stock in the well or usual damage to the well. Any such trouble cocurring in a well one remail in considerable lose in time and creat cureacy in making repairs.

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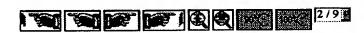
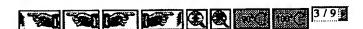




Figure 2 to a sectional when or the apparatus of Figure 1A taken at them 2-21 and

Figure) is a typical plot of applied load versus beliaction for the constent force spring device of the invention.

Referring to the dresings, Figure 14 is the bottom portion of a liner expending tool for one in installing a metallic liner in a well, while Figure 18 Likertrates the statle section of such a tool and Figure 10 represeats the upper services of the tool. The expending tool il is ableshed to stantard well tubing 18 by ampling 15 ont, typically, may be inserved from the surrace through a well easing (not shown) to a point in the owing at which it is easired to install a metallic liner. Before inserting the tool into the well, an alongsted vartically accregated liner 10 fabricated from mild steel, or ether multable emileable meterial, is placed on the tool. The corrugated is secured in position by sentant at its upper end with a cylindrical er marker 16 and, st the lower and by contact with a first-stage espansing die 17 is the form of a tronosted circular core which serves as a firstfixedly obtained to a centrally loanted, elemented sylindrical bollow shaft 18 which forms a portion of the body of the tool. As shown, the expending 610 17 is held in place between a lower aboutder 19 and coller 21 threaded onto the short. . A plurality or movehile arms 69, preservably provided with outsardly salarged portions 85 sear the top, are disposed in the form of a sylindar art 18. The enlarged purtions of the eras 25 upon being coved outcuries; spe limes so hersome spe grant spab on extending the contradered liner into a substantially splintrical shape. The are smallers 22 ere pivotally per 26 although positioned on the sheft to serve as a s shaft to sugage with the arms and more than outwardly. Adventageously, the inside surfaces of the area 92 and the outside surface of expending sember 25 ting sentium, typically cotogonal is shape. The expension of the arm ers is controlled by the position of the master 24 which moves upwardly





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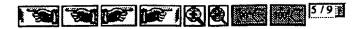
until) it contacts shouldar 26 provided on the claft. As member 26 moves in a documently direction error 22 feld invertily towers the sheft. The expecting arms 22 are held is place on the sheft by collect 27 and circular groups 20

The expending tool, comprising the fivet-stage die and the secondstage die is drawn through the liner to expend it in place in the casing. Due first-stage die provides a gross deformation of the liner so that it is expended outwardly against the well of the sessing. The second-stage die then passes through the liner and performs the final expension to empth the liner surface of the liner and to provide more even content between the liner and the well of the casing and effect a finid-light soul.

In operation, the liner setting tool is assembled at the surface, as on, and a glass shoth saturated with a resizous material may be at the corrugated tube to form the liner. The assembly is lowered the well as the Location at which the liner is to be set. A liquid, such so oil, is then pusped under presence down the well tubing and flows through the percentury 29 provided is golished not 51, through parts 52 and into epitader 35 consected to the upper end of the aboulder 16. Upon the application of pressure to the cylinder, the piston 34 secured to polished rol 31 mower dly in spillader 33. As shows, rod 36 commercia politabel rod 31 and shaft ried the first-stage expending sie 17. Was the piston % neves upperfuly through the sylindar 33 the expanding die 17 and the secondstage die 22 are draws apparelly into the corrugated liner 18 and "iron out" incide wall of the casing in which it is being installed. Positioned on the shaft below the expending member 36 is a communit terce spring number 37 which is employed to true the expending number against the expending some 22 with a substantially sometant force. The force exarted against the arm assistes being substantially constant, the force transmitted through the arm me lists and to the during will be substantially constant so that either sticking of the tool in the casing or repture of the caring is precluded. Of course, the three provided by the spring mester is preselected so that the frintional

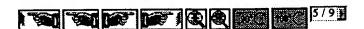


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forces between the tool and the liner and the presence emerted against the oneing are emissioned at predatermined safe levels. The commission force spring
member ensures that the nominal presence between the liner founding purtion 20
of the area 22 is great enough to provide the desired deformation of the obstor, while were making demand to the easing or to the tool.

The equatert force applies sender 77 is alidebly nounted on the abact 10 and hald between the expending alsocat 20 and a cylindrical inver choolder sender 30 (crucing a portion of a differential acrow alsocat 39 which transmits the losding on spring number 37 to short member 10. The differential acrow alsocat comprises short member 16 as the outside of unish are set made threads 15a, the lower member 16 as the outside of unish are set made threads 15a, the lower member 30 provided with tends threads 55a and thinble number 31 provided with threads and the shoulder. The two sets of threads are source, such as square, socialist equare, or done through, to withstand very high loads and differ in pitch so that shoulder 35 is seven appearily on the short 15 when the short is revolved relative to thinble 31. The shoulder 36 is secured to the short 16 by splines 55 so that it can alide longitudinally, but it is not free to rotate on the short. Pressly arisabed to the lower set or the thinble is a friction moder, such as two aprings 42, a hydraulically equated friction and, or other such device for frictionally emerging with the isolds will of the excitation sucher, such as two springs 42, a hydraulically equated friction and, or other such device for frictionally emerging with the isolds will of the excitation of the thinble against frotation with respect to the short. Preferably, the direction of the shoulder should be all thinble to the shoulder sentent 35a, e.g. right-hand threads. Sh, with the pitch rettle being alone to unity. In this summer, cloud-view revolution of the short relative to the thinble summes shoulder sentent 35 to advance upwerd alightly and a compression load in emerted upwardly on spring alassect 37 to usuac Vertical dissector and tive and threads on a chart approximately 1.7-inch outside dissector and tive and threads on the chart approximately 1.7-inch outside dissector and tive and threads





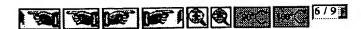
Disastent force spring e) means 31 comprises unions element 13, seventageomaly committing of a plurality of alongsted column disputed around shorts 18. Upper bearing plate sumber the in contact with the apper mode of the solumn end is elikably positioned on shart if to transmit the force of the agring longitudinally against the bottom end of expector sember 24. Lower bearing plate number the contacts the lower mean of the nolumns and is moved specially along the search by lead believe note of the nolumns and is moved to result of revolving differential moves almost 39. Grooves 37 are provided in such of the bearing plates, to form an upper seas and a lower mass, into which the ends of the column are inserted. These grooves may be shaped to confure with the shape of the column such it sanired. A cover 16 may be

A seems for limiting the deflection of the columns is required.

Although the column element functions in a bookled condition, application of progenive accuracy is load thereto would cause total failure or repture of the columns. Therefore, a pair of stope h9 and 85s are provided for this purpose. As shown, the stope are rigidly connected to the bearing plates, and, in affect comprise upper And Lover limiting elements positioned on the shaft to alide longitudinally thereon. The ends of the stope may nown toward, or may from, each other as the load on the spring number varies. Lover showed, or may in prevented from moding down by lower shoulder 36 assessed to the chart 18.

Browner, the spacing between the make is much as to limit the longitudinal travel of the bearing plate machane as they move together to prevent personal deformation of the column almosts to writes alternative manns for preventing shoulds to the column almosts to a stope, or the cover 48 provides of the stimule connections may be employed for this purpose to limit longitudinal and/or internal assistation of columns.

The columns of the column clument 4) may be arranged around the chaft 16, which as shows here forms a portion of the body of the apring device; with made of the columns fitted in the recess 57. The solumns may be



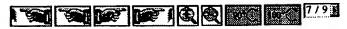
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ritted closely together as above, or may be spaced around the race, with separators used between these to actated the desired spacing. The rusher of policies employed will depend upon column the substitutes and the emisticies of construction. For example, the simularizate ratio of the column may be varied widely, and the column make make may be round, flat, fixed or binged. The practical construction is a thin, element column with rounded ands, from to now within the races shaped to the convenient of the column rate. Externals which may be astisfactoricity employed for the column are on and low alloy steels, chrushes and minimal-chronium statistics stoods, various capper how alloys, such as passapher bronze, beryllium sepport, the high middel alloys and other minimal saturable providing actisfactory mechanical properties. Typically, the individual columns are or long restangular cross-cection, with the width bring greater than the talchness, and arvanged so that the wider race of the unimals is normal to the dimentar of the about. Thus, with nurificiant congruention looking, the columns buckle, and hand about the axis having the loart someth of institutes of institutes of the shart.

by 10.626-inches long, with the ends roused 0.161-inch thick by 0.436-inch wife by 10.626-inches long, with the ends roused, were februated from A.1.8.I \$150 steel, quenched and draws at \$75°F. Buts column was found to require a critical suspension loading of \$50 pounds in order to beakle the enture. After bearing, the selumns were found to have a very flat spring characteristic, as shown in Figure 3, therein Fo is the critical bearing load and point 0 represents the load and deflection at which the stress is the entures fibers of the delumn exceed the yield point of the material. Theoretically, the shape of title spring ubaracteristic curve is described by onews Ca'ABO. Actually, the shape of title spring ubaracteristic curve is described by onews Ca'ABO. Actually, the samplement typical scrating limits, which, of course, say is varied according to the application for which the spring is designed. For example, where a large number of flexing optics are not modeligated, a working stress just below the yield points may be used, while with a great master of flexines, the working stress may be hald to less than the andurence limit of the saterial of construction. In the above-manticoul teats, the latered instruction was limited to

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approximately one imph, at which the longitudinal defloration was approximately 0.225 inches. From more deflection to the section deflection, the \$50-pound loading was found to be substantially constant.

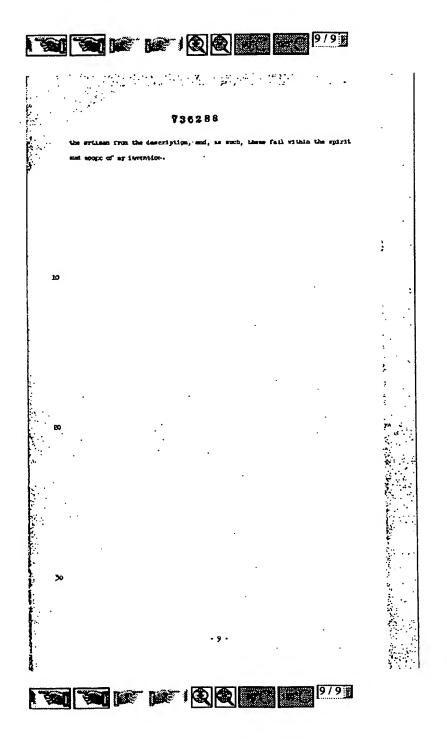
In marchire test a spring device was built, as shows, employing 80 columns, each having a critical buckling load of 1250 pounds. The internal declaration was limited between 0 and about 1.00 inches by suprogrately positioning the storys. Open compressional lossing, the spring element buckled at schetzerically 25,000 pounds and from a longitudinal deflection of 0.00 instead (buckling) to stout 0.15 inches the load rearrant substantially at 25,000

Of course, in designing a spring element as shown it is advantageous to obtain the greatest possible value of long-testinal definations for specified values of laboral deflection and articled bushling load, while unintesting the atrees level to the columns at a cafe level. The preferred columns, therefore, are laminated, as shown in Figures 18 and 2, with entity in flat maker's making up such columns.

In the operation of the above expending tool for setting a liner in well excised, the underspected position. Then the real excessed above, with the area 22 in the retreated position. Then the tool is at the desired level, the well totaling is revolved. The friction number his regarder with the wall of the earing and prevents thinkle his from revolving. With several revolutions of the taking, lower shoulder 35 is nowed agreemily by differential server by to bushle oping alament J7 thich has a predeferminal critical technique for the level is transmitted agreemy agrime the lower ont of expender the, and the topered surface is engaged with the tapered surface on the lacian of the error Et to urgs the large contently with a substantially constant force proportional to the critical bushling load of the syring almost. Subsequently, the expending tool is passed through the liner to expend it in the casing in the meaner described bureaustore.

The foregoing description of a preferred embeliance of my involving has been given for the purpose of acceptification. It will be understood that various medifications in the details of construction will become apparent to

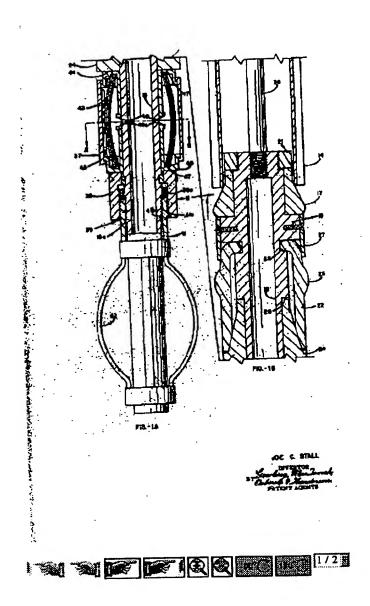




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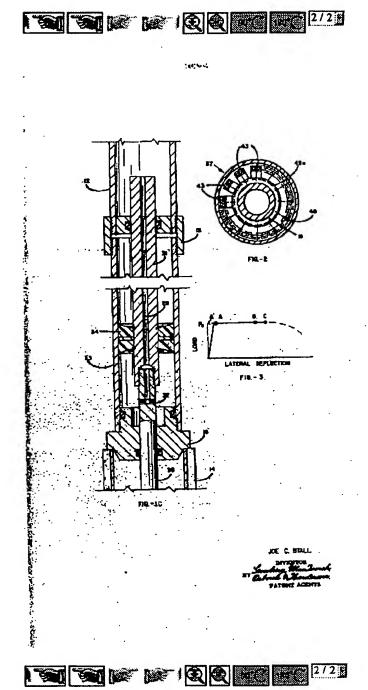


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